PORTLAND CEMENT CONCRETE
FIELD SECTION 501

501.1 SCOPE. To establish uniformity in mix design and inspection of portland cement concrete. The instructions contained in this Section are intended to supplement those contained in the Construction Manual, Sec 500.

501.2 PROCEDURE.

501.2.1 Material Inspection. Each material to be incorporated into a concrete mix is to be inspected and reported in accordance with procedures found in the corresponding section of this Manual. Materials incorporated into commercial mix concrete need not be reported. Calibration of the plant and performance of uniformity tests of concrete are to be performed in accordance with General Sec 10 of this Manual.

501.2.2 Mix Design. The district Operations Engineer is responsible for furnishing concrete mix designs to the Resident Engineer. The mix design should be furnished as soon as the contractor's material sources are known or when requested by Construction. Mix design information should be furnished, by letter, to the Resident Engineer, from the district Operations Engineer. An example of one type of letter is shown as Exhibit 501-A of this Section. In the following paragraphs are two methods of designing concrete mixes. Method A is to be used for designing portland cement concrete pavement mixes and may be used to design masonry concrete mixes. Method B may be used for designing masonry concrete mixes but may not be used for designing pavement mixes. Mix design proportions are to be rounded to the nearest 0.05 except for low slump and latex modified mixes which are to be rounded to the nearest 0.01.

> Note: Some mix design factors are controlled by the specifications. Others are chosen by district personnel. A suggested percent of fine aggregate is 38% for all pavement mixes. For masonry mixes, it is suggested that 36% to 38% fine aggregate be used for air entrained mixes and 40% for non-air entrained mixes. Another suggested design factor is to use a minimum of 6.08 sacks of cement per cubic yard in paving mixes.

501.2.2.1 Method A - Concrete Mix Design by Absolute Volumes.

(a) Design assumptions.

Design a PCCP mix using 15% fly ash, one size coarse aggregate and the following mix parameters:

Cement factor = 6.08 sacks/cu yd

Percent fine aggregate by absolute volume = 38

Water content = 4.9 gal/sack*

Percent air content = 5.5

*Note: This value is chosen well below the specified maximum to allow for expected fluctuations in the mix characteristics during production. When a water-reducing admixture is to be used, the assumed water content would be reduced according to manufacturer's recommendations.

(b) Physical characteristics. Weight per cubic foot, specific gravity, and percent absorption for the aggregates are obtained from "Physical Characteristics of Principal Portland Cement Concrete Aggregates in Missouri" or if sources are new, from test results of samples submitted for rodded unit weight, specific gravity and absorption as received as required in Field Sec 1001 of this Manual. Absolute volume may be obtained from Table 1 of this Section or calculated as follows:

$$\text{Absolute volume} = \frac{\text{Dry rodded unit weight (lb/cu ft)}}{\text{(Specific gravity) x (62.4)}}$$

For the example use:

	Unit Weight (lb/cu ft)	Specific Gravity	Percent Absorption	Abs Vol (cu.ft.)
Fine aggregate - Class A, MO. River	111	2.61	0.4	0.6816
Coarse aggregate - Burlington Limestone	96	2.62	1.0	0.5872
Cement (constant values)	94	3.15	---	0.4782
Fly Ash - MO. Portland, Louisa	94*	2.72	---	0.5538

*Assumed to be equivalent to the unit weight of cement for design purposes.

(c) Design example. Mix proportions are established on a one-sack mix. To determine the absolute volume of the aggregates in a one-sack batch, it is necessary to first determine the total absolute volume of the concrete and the absolute volume of entrained air, cement, and water.

Absolute volumes (cu ft) per sack of cement:

Absolute volume Total concrete $= \dfrac{\text{27.0 cu ft/cu yd}}{\text{6.08 sacks/cu yd}}$

= 4.4408 cu ft/sack

Absolute volume Entrained air $= \dfrac{\text{(Total absolute volume of concrete) x (Percent Air)}}{100}$

$= \dfrac{(4.4408)\ (5.5)}{100}$

= 0.2442 cu ft/sack

Absolute Volume Cement = (0.85) (0.4782)

= 0.4065 cu ft/sack

Absolute Volume Fly Ash = (0.15) (0.5538)

= 0.0831 cu ft/sack

Absolute Volume Water $= \dfrac{\text{4.9 gal/sack}}{\text{7.5 gal/cu ft}}$

= 0.6533 cu ft/sack

Absolute Volume total aggregates = (Total abs. vol conc.) - (Abs. vol. of air, cement, flyash, and water)

= (4.4408) - (0.2442 + 0.4065 + 0.0831 + 0.6533)

= 3.0537 cu ft/sack

Absolute volume Fine aggregates = $\frac{\text{(Total aggr. abs. vol.)(Design percent fine aggr.)}}{100}$

= $\frac{(3.0537)(38)}{100}$

= 1.1604 cu ft/sack

Mix proportions of aggregates are equal to the absolute volume of that aggregate in a one-sack batch divided by the absolute volume of one cubic foot (dry rodded) of that aggregate.

Fine aggregate proportion = $\frac{1.1604}{0.6816}$

= 1.7025

The mix proportion for fine aggregate, rounded to the nearest 0.05, would be 1.70.

Absolute volume Coarse aggregate = (Total aggr. abs. vol.) - (Fine aggr. abs. vol.)

= (3.0537) - (1.70 x 0.6816)

= 1.8950 cu ft/sack

Coarse aggregate proportion = $\frac{1.8950}{0.5872}$

= 3.2272

Therefore, mix proportions rounded to the nearest 0.05, of cement, fine aggregate, and coarse aggregate are:

1: 1.70: 3.25

Mix proportions are defined as the volume of dry-rodded fine aggregate (1.70 cu ft) and coarse aggregate (3.25 cu ft) required for a mix containing one sack (1.0 cu ft) of cementitious material (cement + fly ash). After mix proportions have been established, the mix characteristics, including total yield for a one cubic yard batch, shall be calculated as shown in paragraphs 501.2.3 through 501.2.3.5 of this Section.

501.2.2.2 Method B - Concrete Mix Design for any Cement Factor and any Percent Excess Mortar.

(a) Design assumptions.

Design a B-1 mix using 15% fly ash and the following mix parameters:

Cement factor	=	6.60 sacks/cu yd
Percent desired excess mortar	=	90
Percent air content	=	5.5

(b) Physical characteristics. Weight per cubic foot, specific gravity, and percent absorption for the aggregate are obtained from "Physical Characteristics of Principal Portland Cement Concrete Aggregates in Missouri" or if sources are new, from test results of samples submitted for rodded unit weight, specific gravity, and absorption-as-received, as required in Field Sec 1001 of this Manual. Absolute volume may be obtained from Table 1 of this Section or calculated as follows:

$$\text{Absolute volume} = \frac{\text{Dry rodded unit weight (lbs/cu ft)}}{\text{(Specific gravity) x (62.4)}}$$

For the example use,

	Unit Weight (lb/cu.ft)	Specific Gravity	Percent Absorption	Abs Vol (cu ft)
Fine aggregate - Class A, Mo.River	111	2.61	0.4	0.6816
Coarse aggregate - Burlington Limestone	96	2.62	1.0	0.5872
Cement (constant values)	94	3.15	---	0.4782
Fly Ash - Mo. Portland,Louisa	94*	2.72	---	0.5538

*Assumed to be equivalent to the unit weight of cement for design purposes.

(c) Design example. The mix proportions are established on a one sack mix. This method of design requires that the coarse aggregate content be solved first. The cement, fly ash, air, and water content are known from the assumptions for design. Let "A" equal the cubic feet of coarse aggregate (dry rodded) required for a one-sack batch.

Absolute volumes (cu ft) per sack of cement:

$$\text{Absolute volume Total concrete} = \frac{\text{27.0 cu ft/cu yd}}{\text{6.60 sacks/cu yd}}$$

$$= \text{4.0909 cu ft/sack}$$

Absolute volume Coarse aggregate = (Coarse aggregate content) (Absolute volume of 1 cu ft dry rodded aggregate)

= 0.5872 (A) cu ft/sack

Absolute volume mortar = (Total vol of conc) - (Abs vol of coarse aggr)

= [(4.0909) - (0.5872) (A)] cu ft/sack (Equation 1)

Since the design is assuming 90 percent more mortar than is necessary to fill the voids in the coarse aggregate, solve for the cubic feet of voids in the coarse aggregate and multiply by 1.90 to determine absolute vdume of mortar.

Voids in coarse aggregate	=	(Coarse aggr content) - (Abs vol of coarse aggr)
	=	(A) - (0.5872) (A)
	=	0.4128 (A) cu ft/sack
Absolute volume of mortar	=	(0.4128) (A) x (1.90)
	=	0.7843 (A) cu ft/sack (Equation 2)

The absolute volume of mortar is set to two equations, both containing the unknown coarse aggregate content "A". Solve the two equations for coarse aggregate as follows:

0.7843 (A)	=	4.0909 - 0.5872 (A)
1.3715 (A)	=	4.0909
A	=	2.9828 cu ft/sack
		Rounded to the nearest 0.05, use 3.00 cu ft/sack

The method of calculation of the coarse aggregate content shown in this paragraph could have been summarized in the following formula:

$$A = \frac{\frac{27}{C.F.}}{(1 - VCA)\left(\frac{100 + E.M.}{100}\right) + VCA}$$

Where:

A	=	Coarse aggregate content
C.F.	=	Cement factor, sacks
E.M.	=	Percent excess mortar
VCA	=	Absolute volume of one cubic foot of coarse aggregate.

To determine the absolute volume of fine aggregate in a one-sack batch, deduct the sum of absolute volumes of coarse aggregate, cement, fly ash, air and water from the total absolute volume of concrete per one-sack batch.

Absolute volume fine aggregate = (Total absolute volume concrete) - (Absolute volume coarse aggregate + cement + fly ash+air + water)

Absolute volumes (cu ft) per sack of cement:

Absolute volume coarse aggregate	=	(Coarse aggregate content) x (Absolute volume of 1 cu ft)
	=	(3.00) x (0.5872)
	=	1.7616 cu ft/sack

Absolute volume cement	=	(0.85) (0.4782)
	=	0.4065 cu ft/sack
Absolute volume fly ash	=	(0.15) (0.5538)
	=	0.0831 cu ft/sack
Absolute volume entrained air	=	$\frac{\text{(Total absolute volume of concrete) (Percent air)}}{100}$
	=	$\frac{(4.0909) \times (5.5)}{100}$
	=	0.2250 cu ft/sack
Absolute volume water	=	$\frac{\text{5.0 gal/sack}}{\text{7.5 gal/cu ft}}$
	=	0.6667 cu ft/sack
Absolute volume fine aggregate	=	(Total abs vol conc) - (Abs vol coarse aggr) + cement + fly ash+ air + water)
	=	(4.0909) - (1.7616 + 0.4065 + 0.0831 + 0.2250 + 0.6667)
	=	0.9480 cu ft/sack
Volume of dry rodded fine aggregate	=	$\frac{\text{Abs. vol. of fine aggregate}}{\text{Abs. vol. of 1 cu. ft. of dry rodded aggr.}}$
	=	$\frac{0.9480}{0.6816}$
	=	1.3908 cy ft/sack Rounded to the nearest 0.05, use 1.40 cu.ft./sack.

Therefore, mix proportions, rounded to the nearest 0.05, of cement, fine aggregate and coarse aggregate are:

1: 1.40: 3.00

After mix proportions have been established, the mix characteristics, including total yield for a one cubic yard batch, shall be calculated as shown in paragraphs 501.2.3 through 501.2.3.5 of this Section.

501.2.3 Mix Characteristics. The characteristics of the concrete mixture shall be calculated to verify that the mix proportions will result in a mix having the characteristics assumed for design. Characteristics of design mixtures should be furnished to the Resident Engineer with the mix proportions. After the proportions are established by either Method A or B, the calculations for mix characteristics are the same. For the purpose of this example, the proportions and materials from Method A will be used.

501.2.3.1 Cement Factor. The cement factor is defined as the cement content in sacks per cubic yard of concrete, based on the absolute volumes of all the ingredients, including entrained air when specified. By arranging the calculations in the following sequence, the dry yield (absolute volume of cement, fine aggregate, and coarse aggregate) and yield with entrained air may be determined for use in later calculations. The absolute volumes are determined for a one-sack batch.

Absolute volumes (cu ft) per sack of cement:

Absolute volume cement	=	(0.85) (0.4782)
	=	0.4065 cu ft/sack
Absolute volume fly ash	=	(0.15) (0.5538)
	=	0.0831 cu ft/sack
Absolute volume fine aggregate	=	(Mix prop) x (Abs vol of 1 cu ft dry rodded fine aggr)
	=	(1.70) x (0.6816) = 1.1587 cu ft/sack
Absolute volume coarse aggregate	=	(Mix prop) x (Abs vol of 1 cu ft dry rodded coarse aggr)
	=	(3.25) x (0.5872) = 1.9084 cu ft/sack
Dry yield of one-sack batch	=	Total dry abs vol of cement, fly ash, fine aggr, and coarse aggr
	=	(0.4065) + (0.0831)+ (1.1587) + (1.9084)
	=	3.5567 cu ft/sack
Absolute volume of water	=	$\frac{\text{4.9 gal/sack}}{\text{7.5 gal/cu ft}}$
	=	0.6533 cu ft/sack
Yield without entrained air	=	(Dry yield) + (Absolute volume of water)
	=	(3.5567) + (0.6533)
	=	4.2100 cu ft/sack
Yield with entrained air	=	$\dfrac{\text{Yield without entrained air}}{\frac{(100 - \text{Percent air})}{100}}$
	=	$\dfrac{4.2100}{\frac{(100 - 5.5)}{100}}$
	=	$\dfrac{4.2100}{0.945}$
	=	4.4550 cu ft/sack

Absolute volume of entrained air = (Yield with entrained air) - (Yield without entrained air)

= 4.4550 - 4.2100

= 0.2450 cu ft/sack

The cement factor is determined by dividing 27.0 cu ft (1 cu.yd.) by the absolute volume of concrete produced (yield with entrained air) from a one-sack mix.

$$\text{Cement factor} = \frac{\text{27.0 cu ft/cu yd}}{\text{Yield with entrained air of one-sack batch}}$$

$$= \frac{27.0}{4.4550}$$

= 6.06 sacks/cu yd

501.2.3.2 Percent excess mortar. Excess mortar is the amount of mortar contained in the mixture that is not needed to fill the voids in the coarse aggregate. These voids can be visualized as the unfilled space in a container of dry-rodded coarse aggregate. Mortar is that part of the mixture consisting of fine aggregate, cement, fly ash, water, and air. To calculate the percent excess mortar, the voids in the coarse aggregate and the absolute volume of mortar must be calculated. The calculations are based on a one-sack batch.

Voids in dry-rodded coarse aggregate = (Cubic feet of dry rodded coarse aggregate, the design mix proportion) - (Absolute volume of coarse aggregate in a one-sack batch)

= 3.25 - (3.25 x 0.5872)

= 3.25 - 1.9084

= 1.3416 cu ft/sack

Absolute volume of mortar = Sum of abs vol of fine aggr, cement, fly ash, water, and air (See calculations for factor)

= 1.1587 + 0.4065 + 0.0831 + 0.6533 + 0.2450

= 2.5466 cu ft/sack

$$\text{Percent excess Mortar} = \frac{\text{[Abs vol of mortar - Voids in dry-rod coarse aggr] x 100}}{\text{Voids in dry-rodded coarse aggregate}}$$

$$= \frac{(2.5466 - 1.3416) \times 100}{1.3416}$$

= 89.82%, rounds to 90%

501.2.3.3 Percent fine aggregate. If Method A is used for mix design, it is beneficial, for purposes of verifying the design, to calculate the percent fine aggregate by absolute volume.

Percent fine Aggregate	=	$\dfrac{\text{Absolute volume of fine aggregate x 100}}{\text{(Abs vol of fine aggr + Abs vol of coarse aggr)}}$
	=	$\dfrac{1.1587}{1.1587 + 1.9084} \times 100$
	=	37.78%, rounds to 38%

501.2.3.4 Dry weights per cubic yard batch. All calculations to this point have been based on a one-sack batch. To determine the amounts of each ingredient, on a dry basis, contained in a cubic yard batch multiply the mix proportion for that ingredient by the number of sacks of cement (cement factor) per cubic yard by the unit weight of that ingredient. Round the results to the nearest pound.

Dry weight per cubic yard batch	=	(Mix proportion) x (Cement factor) x (Dry rodded unit weight)
Cement	=	1 x (0.85) x (6.06 sacks/cu yd) x (94 lb/sack)
	=	486 lb/cu. yd.
Fly Ash	=	1 x (0.15) x (6.06 sacks/cu.yd.) x (94 lb./sack)
	=	86 lb/cu. yd.
Fine aggregate	=	1.70 x (6.08 sacks/cu yd) x (111 lb/cu ft)
	=	1147 lb/cu yd
Coarse aggregate	=	3.25 x (6.08 sacks/cu yd) x (96 lb/cu ft)
	=	1897 lb/cu yd

501.2.3.5 Yield per cubic yard batch. The dry yield and yield with entrained air for a one-sack batch were determined as an intermediate step in calculating the cement factor in paragraph 501.2.3.1 of this Section. To determine dry yield for a one cubic yard batch, multiply the dry yield for a one-sack batch by the cement factor, in sacks.

Dry yield	=	3.5567 x 6.06
	=	21.62 cu ft per cubic yard

To determine total yield for a one cubic yard batch, multiply the yield with entrained air for a one-sack batch by the cement factor, in sacks.

Total yield	=	4.4550 x 6.06
	=	27.09 cu ft

501.2.3.6 Percent Air in Mortar. Air entrainment is generally considered effective for freeze-thaw resistance when the volume of air in the mortar fraction of the concrete (material passing the No. 4 sieve) is about 9% ± 1%.

The following procedure is to be used to compute this value.

$$\text{Percent Air in Mortar} = \frac{(\text{Abs. vol. of entrained air}) \times 100}{(\text{Abs. vol. total conc. in one-sack batch} - \text{Abs. vol. coarse agg.})}$$

$$= \frac{(0.2450) \times 100}{(4.4550) - (1.9084)}$$

$$= 9.6207$$

Rounded to the nearest 0.1%, the Percent Air in Mortar for this mix is 9.6%.

Generally, this value will not fluctuate outside of the 8 to 10 percent range when using an assumed air content of 5.5% and the percentages of fine aggregate as suggested in Section 501.2.2. The amount of material in the coarse aggregate passing the No. 4 sieve is considered to be negligible for the purpose of this design check.

501.2.4 Field Proportions. The proportion of the various materials to be incorporated into the mix, the effective water, the scale weights, yield, and cement factor may be determined from the equations and procedures described in Sec 501.6 of the Construction Manual.

501.3 REPORT. Data collected at the concrete plant, or related to the day's production, shall be documented in SiteManager as sample records. A concrete plant inspector's daily report may be printed using Impromptu (Concrete Plant Inspectors Report) and distributed as described in Sec 500 of the Construction Manual.

501.4 PRECAST CONCRETE. The use of approved high range water-reducers and non-chloride accelerators will be permitted for use in precast concrete having a minimum cement content of 564 pounds and no other specific air or slump mix requirements, if approved by the district Operations Engineer except for concrete pipe. Requests for additives to concrete pipe should be directed to the State Materials Engineer.

501.4.1 The producer shall furnish a mix design to the district Operations Engineer, for approval, which shall indicate the batch weights, including the amount of admixture(s) to be used.

501.4.2 The admixture(s) are to be within the manufacturer's recommended dosage levels.

501.4.3 The accelerators shall be of the non-chloride type.

501.4.4 The supplier of the high range water-reducer shall furnish for the district Operations Engineer's file, a certification stating the admixture being furnished is considered to be compatible with the other admixtures (i.e., air entrainment, retarder, accelerator, etc. by brand name) being used in the mixture. Any changes in sources of admixtures will require a re-submittal of the certification.

501.4.5 A copy of the approval of the mix design using the above admixtures shall be submitted to the State Materials Engineer.

501.5 CLASS A-1 CONCRETE. Class A-1 Concrete was created for prestress work. It provides a smaller aggregate, which is necessary to accommodate the often minimal clearance between forms and reinforcement, or within the reinforcement cage. It also provides additional cement to accommodate the water demand associated with the smaller rock, and to obtain faster strength gain. Class A-1 Concrete for work other than prestress may be modified as follows.

501.5.1 Grade D stone may be substituted for Grade E stone, when the piece being cast does not have clearance problems that might cause Grade D stone to bridge and cause voids or low density areas within the piece. When the District and the precaster are in agreement on the desirability of the Grade D substitution, Headquarters Materials shall be contacted with the proposal.

501.5.2 Headquarters Materials will review the proposal and will approve or disapprove the substitution of Grade D stone for Grade E stone in the designated application.

501.5.3 Following approval by Headquarters Materials, a no-cost change order shall be issued on the associated contract to record the intent to use a non-specified substitution of material.

TABLE 1
FIELD SECTION 501
Absolute Volumes Per Cubic Foot of Material

Specific Gravity	Weight per cubic foot in pounds 80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
2.36	.5432	.5500	.5568	.5636	.5704	.5772	.5840	.5908	.5976	.6044	.6111	.6179	.6247	.6315	.6383
2.37	.5409	.5477	.5545	.5612	.5680	.5748	.5815	.5883	.5950	.6018	.6086	.6153	.6221	.6289	.6356
2.38	.5387	.5454	.5521	.5589	.5656	.5723	.5791	.5858	.5925	.5993	.6060	.6127	.6195	.6262	.6329
2.39	.5364	.5461	.5498	.5565	.5632	.5699	.5767	.5834	.5901	.5968	.6035	.6102	.6169	6236	.6303
2.40	.5342	.5409	.5475	.5542	.5609	.5676	.5743	.5809	.5876	.5943	.6010	.6076	.6143	.6210	.6277
2.41.	.5320	.5386	.5453	.5519	.5586	.5652	.5719	.5785	.5852	.5918	.5985	.6051	.6118	.6184	.6251
2.42	.5298	.5364	.5430	.5496	.5563	.5629	.5695	.5761	.5728	.5894	.5960	.6026	.6092	.6159	.6225
2.43	.5276	.5342	.5408	.5474	.5540	.5606	.5672	.5738	.5804	.5869	.5935	.6001	.6067	.6133	.6199
2.44	.5254	.5320	.5386	.5451	.5517	.5583	.5648	.5714	.5780	.5845	.5911	.5977	.6042	.6108	.6174
2.45	.5233	.5298	.5364	.5429	.5495	.5560	.5625	.5691	.5756	.5822	.5887	.5952	.6018	.6083	.6149
2.46	.5212	.5277	.5342	.5407	.5472	.5537	.5602	.5668	.5733	.5798	.5863	.5928	.5993	.6058	.6124
2.47	.5190	.5255	.5320	.5385	.5450	.5515	.5580	.5645	.5710	.5774	.5839	.5904	.5969	.6034	.6099
2.48	.5170	.5234	.5299	.5363	.5428	.5493	.5557	.5622	.5687	.5751	.5816	.5880	.5945	.6010	.6074
2.49	.5149	.5213	.5278	.5342	.5406	.5471	.5535	.5599	.5664	.5728	.5792	.5857	.5921	.5985	.6050
2.50	.5128	.5192	.5256	.5321	.5385	.5449	.5513	.5577	.5641	.5705	.5769	.5833	.5897	.5962	.6026
2.51	.5108	.5172	.5235	.5299	.5363	.5427	.5491	.5555	.5619	.5682	.5746	.5810	.5874	.5938	.6002
2.52	.5088	.5151	.5215	.5278	.5342	.5405	.5469	.5533	.5596	.5660	.5723	.5787	.5851	.5914	.5978
2.53	.5067	.5131	.5194	.5257	.5321	.5384	.5447	.5511	.5574	.5637	.5701	.5764	.5828	.5891	.5954
2.54	.5047	.5111	.5174	.5237	.5300	.5363	.5426	.5489	.5552	.5615	.5678	.5741	.5805	.5868	.5931
2.55	.5028	.5090	5153	.5216	.5279	.5342	.5405	.5468	.5530	.5593	.5656	.5719	.5782	.5845	.5907
2.56	.5008	.5071	.5133	.5196	.5258	.5321	.5384	.5446	.5509	.5571	.5634	.5697	.5759	.5822	.5884
2.57	.4989	.5051	.5113	.5176	.5238	.5300	.5363	.5425	.5487	.5550	.5612	5674	.5737	.5799	.5862
2.58	.4969	.5031	.5093	.5156	.5218	.5280	.5342	.5404	.5466	.5528	.5590	.5652	.5715	.5777	.5839
2.59	.4950	.5012	.5074	.5136	.5198	.5259	.5321	.5383	.5445	.5507	.5569	.5631	.5693	.5754	.5816
2.60	.4931	.4993	.5054	.5116	.5178	.5239	.5301	.5362	.5424	.5486	.5547	.5609	.5671	.5732	.5794
2.61	.4912	.4973	.5035	.5096	.5158	.5219	.5280	.5342	.5403	.5465	.5626	.5587	.5649	.5710	.5772
2.62	.4893	.4954	.5016	.5077	.5138	.5199	.5260	.5321	.5383	.5444	.5505	.5566	.5627	5688	.5750
2.63	.4875	.4936	.4997	.5058	.5118	.5179	.5240	.5301	.5362	.5423	.5484	.5545	.5606	.5667	.5728
2.64	.4856	.4917	.4978	.5038	.5099	.5160	.5220	.5281	.5342	.5403	.5463	.5524	.5585	.5645	.5706
2.65	.4838	.4898	.4959	.5019	.5080	.5140	.5201	.5261	.5322	.5382	.5443	.5503	.5564	.5624	.5685
2.66	.4820	.4880	.4940	.5000	.5061	.5121	.5181	.5241	.5302	.5362	.5422	.5482	.5543	.5603	.5663
2.67	.4802	.4862	.4922	.4982	.5042	.5102	.5162	.5222	.5282	.5342	.5402	.5462	.5522	.5582	.5642
2.68	.4784	.4844	.4903	.4963	.5023	.5083	.5143	.5202	.5262	.5322	.5382	.5442	.5501	.5561	.5621
2.69	.4766	.4826	.4885	.4945	.5004	.5064	.5123	.5183	.5243	.5302	.5362	.5421	.5481	.5540	.5600
2.70	.4748	.4808	.4867	.4926	.4986	.5045	.5104	.5164	.5223	.5283	.5342	.5401	.5461	.5520	.5579
2.71	.4731	.4790	.4849	.4908	.4967	.5026	.5086	.5145	.5204	.5263	.5322	.5381	.5440	.5500	.5559
2.72	.4713	.4772	.4831	.4890	.4949	.5008	.5067	.5126	.5185	.5244	.5303	.5362	.5420	.5479	.5538
2.73	.4696	.4755	.4814	.4872	.4931	.4990	.5048	.5107	.5166	.5224	.5283	.5342	.5401	.5459	.5518
2.74	.4679	.4738	.4796	.4854	.4913	.4971	.5030	.5088	.5147	.5205	.5264	.5322	.5381	.5439	.5498
2.75	.4662	.4720	.4779	.4837	.4895	.4953	.5012	.5070	.5128	.5186	.5245	.5303	.5361	.5420	.5478
2.76	.4645	.4703	.4761	.4819	.4877	.4935	.4993	.5052	.5110	.5168	.5226	.5284	.5342	.5400	.5458
2.77	.4628	.4686	.4744	.4802	.4860	.4918	.4975	.5033	.5091	.5149	.5207	.5265	.5323	.5380	.5438
2.78	.4612	.4669	.4727	.4785	.4842	.4900	.4958	.5015	.5073	.5131	.5188	.5246	.5303	.5361	.5419
2.79	.4595	.4653	.4710	.4767	.4825	.4882	.4940	.4997	.5055	.5112	.5170	.5227	.5284	.5342	.5399
2.80	.4579	.4636	.4693	.4750	.4808	.4865	.4922	.4979	.5037	.5094	.5151	5208	.5266	.5323	.5380
2.81	.4562	.4619	.4677	.4734	.4791	.4848	.4905	.4962	.5019	.5076	.5133	.5190	.5247	.5304	.5361
2.82	.4546	.4603	.4660	.4717	.4774	.4830	.4887	.4944	.5001	.5058	.5115	.5171	.5228	.5285	.5342
2.83	.4530	.4587	.4643	.4700	.4757	.4813	.4870	.4927	.4983	.5040	.5096	.5153	.5210	.5266	.5323
2.84	.4514	.4571	.4627	.4684	.4740	.4796	.4853	.4909	.4966	.5022	.5079	.5135	.5191	.5248	.5304
2.85	.4498	.4555	.4611	.4667	.4723	.4780	.4836	.4892	.4948	.5004	.5061	.5117	.5173	5229	.5286

TABLE 1 (Cont'd)
FIELD SECTION 501
Absolute Volumes Per Cubic Foot of Material

Specific Gravity	Weight per cubic foot in pounds 95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
2.36	.6451	.6519	.6587	.6655	.6723	.6791	.6858	.6926	.6994	.7062	.7130	.7198	.7266	.7334	.7402
2.37	.6424	.6491	.6559	.6627	.6694	.6762	.6829	.6897	.6965	.7032	.7100	.7168	.4235	.7303	.7370
2.38	.6397	.6464	.6531	.6599	.6666	.6733	.6801	.6868	.6935	.7003	.7070	.7137	.7205	.7272	.7339
2.39	.6370	.6437	.6504	.6571	.6638	.6705	.5772	.6839	.6906	.6974	.7401	.7108	.7175	.7242	.7309
2.40	.6343	.6410	.5477	.6544	.6611	.6677	.5744	.6811	.6878	.6944	.7011	.7078	.7145	.7212	.7278
2.41	.6317	.6384	.6450	.6517	.6583	.6583	.6650	.6716	.6783	.6849	.6916	.6983	.7049	.7115	.7182
2.42	.6291	.6357	.6424	.6490	.6556	.6622	.6688	.6755	.6821	.6887	.6953	.7019	.7086	.7152	.7218
2.43	.6265	.6331	.6397	.6463	.6529	.6595	.6661	.6727	.6793	.6859	.6825	.6991	.7057	.7123	.7188
2.44	.6239	.6305	.6371	.6437	.6502	.6568	.6634	.6699	.6765	.6831	.6896	.6962	.7028	.7093	.7159
2.45	.6214	.6279	.6345	.6410	.6476	.6541	.6606	.6672	.6737	.6803	.6868	.6934	.6999	.7064	.7130
2.46	.6189	.6254	.6319	.6384	.6449	.6514	.6580	.6645	.6710	.6775	.6840	.6905	.6971	.7036	.7101
2.47	.6164	.6229	.6293	.6358	.6423	.6488	.6553	.6618	.6683	.6748	.6813	.6877	.6942	.7007	.7072
2.48	.6139	.6203	.6268	.6333	.6397	.6462	.6527	6591	.6656	.6720	.6785	.6850	.6914	.6979	.7004
2.49	.6114	.6179	.6243	.6307	.6372	.6436	.6500	.6565	.6629	.6693	.6758	.6822	.6887	.6951	.7015
2.50	.6090	.6154	.6218	.6282	.6346	.6410	.6474	.6538	.6603	.6667	.6731	.6795	.6859	.6923	.6987
2.51	.6065	.6129	.6193	.6257	.6321	.6385	.6449	.6512	.6576	.6640	.6704	.6768	.6832	.6895	.6959
2.52	.6041	.6105	.6169	.6232	.6296	.6359	.6423	.6487	.6550	.6614	.6677	.6741	.6805	.6868	.6932
2.53	.6018	.6081	.6144	.6208	.6271	.6334	.6398	.6461	.6524	6588	.6651	.6714	.6778	.6841	.6904
2.54	.5994	.6057	.6120	.6183	.6246	.6309	.6372	.6435	.6499	.6562	.6625	.6688	.6751	.6814	.6877
2.55	.5970	.6033	.6096	.6159	.6222	.6285	.6347	.6410	.6473	.6536	.6599	.6662	.6724	.6787	.6850
2.56	.5947	.6010	.6072	.6135	.6197	.6260	.3623	.6385	.6448	.6510	.6573	.6636	.6698	.6761	.6823
2.57	.5924	.5986	.6049	.6111	.6173	.6236	.6298	.6360	.6423	.6485	.6547	.6610	.6672	.6735	.6797
2.58	.5901	.5963	.6025	.6087	.6149	.6211	.6274	.6336	.6398	.6460	.6522	.6584	.6646	.6708	.6771
2.59	.5878	.5940	.6002	.6064	.6126	.6188	.6249	.6311	.6373	.6435	.6497	.6559	.6621	.6683	.6744
2.60	.5856	.5917	.5979	.6040	.6102	.6164	.6225	.6287	.6349	.6410	.6472	.6534	.6595	.6657	.6718
2.61	.5833	.5894	.5956	.6017	.6079	.6140	.6201	.6263	.6324	.6386	.6447	.6508	.6570	.6631	.6693
2.62	.5811	.5872	.5933	.5994	.6055	.6117	.6178	.6239	.6300	.6361	.6422	.6484	.6545	.6606	.6667
2.63	.5789	.5850	.5911	.5972	.6032	.6093	.6454	.6215	.6276	.6337	.6398	.6459	.6520	.6581	.6642
2.64	.5767	.5828	.5888	.5949	.6010	.6070	.6131	.6192	.6252	.6313	.6374	.6435	.6495	.6556	.6617
2.65	.5745	.5806	.5866	.5926	.5987	.6047	.6108	.6168	.6229	.6289	.6350	.6410	.6471	.6531	.6592
2.66	.5723	.5784	.5844	.5904	.5964	6025	.6085	.6145	.6205	.6266	.6326	.6386	.6446	.6507	.6567
2.67	.5702	35762	.5822	.5882	.5942	.6002	.6062	.6122	.6182	.6242	.6302	.6362	.6422	.6482	.6542
2.68	.5681	.5741	.5800	.5860	.5920	.5980	.6040	.6099	.6159	.6219	.6279	.6338	.6398	.6458	.6518
2.69	.5660	.5719	.5779	.5838	.5898	.5957	.6017	.6077	.6136	.6196	.6255	.6315	.6375	.6434	.6494
2.70	.5639	.5698	.5757	.5817	.5876	.5935	.5995	.6054	.6113	.6173	.6232	.6292	.6351	.6410	.6470
2.71	.5618	.5677	.5736	.5795	.5854	.5914	.5973	.6032	.6091	.6150	.6209	.6268	.6327	.6387	.6446
2.72	.5597	.5656	.5715	.5774	.5833	.5892	.5951	.6010	.6069	.6127	.6186	.6245	.6304	.6363	.6422
2.73	.5577	.5636	.5694	.5753	.5811	.5870	.5929	.5988	.6046	.6105	.6164	.6222	.6281	.6340	.6399
2.74	.5556	.5615	.5673	.5732	.5790	.5849	.5907	.6966	.6024	.6083	.6141	.6200	.6258	.6317	.6375
2.75	.5536	.5594	.5653	.5711	.5769	.5828	.5886	.5944	.6002	.6061	.6119	.6177	.6235	.6294	.6352
2.76	.5516	.5574	.5632	.5690	.5748	.5806	.5864	.5923	.5981	.6039	.6097	.6155	.6213	.6271	.6329
2.77	.5496	.5554	.5612	.5670	.5728	.5785	.5843	.5901	.5959	.6017	.6075	.6133	.6190	.6248	.6306
2.78	.5476	.5534	.5592	.5649	.5707	.5765	.5822	.5880	.5938	.5995	.6053	.6110	.6168	.6226	.6283
2.79	.5457	.5514	.5572	.5629	.5687	.5744	.5801	.5859	.5916	.5974	.6031	.6089	.6146	.6203	.6261
2.80	.5437	.5495	.5552	.5609	.5666	.5723	.5781	.5838	.5895	.5952	.6010	.6067	.6124	.6181	.6239
2.81	.5418	.5475	.5532	.5589	.5646	.5703	.5760	.5817	.5874	.5931	.5988	.6045	.6102	.6159	.6216
2.82	.5399	.5456	.5512	.5569	.5626	.5683	.5740	.5797	.5853	.5910	.5967	.6024	.6081	.6137	.6194
2.83	.5380	.5436	.5493	.5550	.5606	.5663	.5719	.5776	.5833	.5889	.5946	.6003	.6059	.6116	.6172
2.84	.5361	.5417	.5474	.5530	.5586	.5643	.5699	.5756	.5812	.5869	.5925	.5981	.6038	.6094	.6151
2.85	.5342	.5398	.5454	.5511	.5567	.5623	.5679	.5735	.5792	.5848	.5904	.5960	.6017	.6073	.6129

TABLE 1 (Cont'd)
FIELD SECTION 501
Absolute Volumes Per Cubic Foot of Material

Specific Gravity	Weight per cubic foot in pounds 110	111	112	113	114	115	116	117	118	119	120	121	122	123	124
2.36	.7470	.7537	.7602	.7673	.7741	.7809	.7877	.7945	.8013	.8081	.8149	.8217	.8284	.8352	.8420
2.37	.7438	.7506	.7573	.7641	.7709	.7776	.7844	.7911	.7979	.8047	.8114	.8182	.8249	.8317	.8385
2.38	.7407	.7474	.7541	.7609	.7676	.7743	.7811	.7878	.7945	.8013	.8080	.8147	.8215	.8282	.8349
2.39	.7376	.7443	.7510	.7577	.7644	.7711	.7778	.7845	.7912	.7979	.8046	.8113	.8180	.8248	.8315
2.40	.7345	.7412	.7479	.7545	.7612	.7679	.7746	.7812	.7879	.7946	.8013	.8080	.8146	.8213	.8280
2.41	.7315	.7381	.7448	.7514	.7581	.7647	.7714	.7780	.7847	.7913	.7980	.8046	.8113	.8179	.8246
2.42	.7284	.7351	.7417	.7483	.7549	.7615	.7682	.7748	.7814	.7880	.7947	.8013	.8079	.8145	.8211
2.43	.7254	.7320	.7386	.7452	.7518	.7584	.7950	.7716	.7782	.7848	.7914	.7980	.8046	.8112	.8178
2.44	.7225	.7290	.7356	.7422	.7487	.7553	.7619	.7684	.7750	.7816	.7881	.7947	.8013	.8078	.8144
2.45	.7195	.7261	.7326	.7391	.7457	.7522	.7588	.7653	.7718	.7784	.7849	.7915	.7980	.8046	.8111
2.46	.7166	.7231	.7296	.7361	.7427	.7492	.7557	.7622	.7687	.7752	.7817	.7883	.7948	.8013	.8078
2.47	.7137	.8202	.7267	.7332	.7396	.7461	.7526	.7591	.7656	.7721	.7786	.7851	.7915	.7980	.8045
2.48	.7108	.7173	.7237	.7302	.7367	.7431	.7496	.7560	.7625	.7690	.7754	.7819	.7884	.7948	.8013
2.49	.7080	.7144	.7208	.7273	.7337	.7401	.7466	.7530	.7594	.7659	.7723	.7788	.7852	.7916	.7981
2.50	.7051	.7115	.7179	.7244	.7308	.7372	.7436	.7500	.7564	.7628	.7692	.7756	.7821	.7885	.7949
2.51	.7023	.7087	.7151	.7215	.7279	.7342	.7406	.7470	.7534	.7598	.7662	.7726	.7789	.7853	.7912
2.52	.6995	.7059	.7123	.7186	.7250	.7313	.7377	.7440	.7504	.7568	.7631	.7695	.7758	.7822	.7886
2.53	.6968	.7031	.7094	.7158	.7221	.7284	.7348	.7411	.7474	.7538	.7601	.7664	.7728	.7791	.7854
2.54	.6940	.7003	.7066	.7130	.7193	.7256	.7319	.7382	.7445	.7508	.7571	.7634	.7697	.7760	.7824
2.55	.6913	.6976	.7039	.7102	.7164	.7227	.7290	.7353	.7416	.7479	.7541	.7604	.7667	.7730	.7793
2.56	.6886	.6949	.7011	.7074	.7136	.7199	.7262	.7324	.7387	.7449	.7512	.7575	.7637	.7700	.7762
2.57	.6859	.6922	.6984	.7046	.7109	.7171	.7233	.7296	.7358	.7420	.7483	.7545	.7608	.7670	.7732
2.58	.6833	.6895	.6957	.7019	.7081	.7143	.7205	.7267	.7330	.7392	.7454	.7516	.7578	.7640	.7702
2.59	.6806	.6868	.6930	.6992	.7054	.7116	.7178	.7239	.7301	.7363	.7425	.7487	.7549	.7611	.7673
2.60	.6780	.6842	.6903	.6965	.7027	.7088	.7150	.7212	.7273	.7335	.7396	.7458	.7520	.7581	.7643
2.61	.6754	.6816	.6877	.6938	.7000	.7061	.7123	.7184	.7245	.7307	.7368	.7430	.7491	.7552	.7614
2.62	.6728	.6789	.6851	.6912	.6973	.7034	7095	.7156	.7218	.7279	.7340	.7401	.7462	.7523	.7585
2.63	.6703	.6764	.6825	.6886	.6946	.7007	.7068	.7129	.7190	.7251	.7312	.7373	.7434	.7495	.7556
2.64	.6677	.6738	.6799	.6859	.6920	.6981	.7042	.7102	.7163	.7224	.7284	.7345	.7406	.7466	.7527
2.65	.6652	.6713	.6773	.6834	.6894	.6955	.7015	.7075	.7136	.7196	.7257	.7317	.7378	.7438	.7499
2.66	.6627	.6687	.6748	.6808	.6868	.6928	.6989	.7049	.7109	.7169	.7230	.7290	.7350	.7410	.7471
2.67	.6602	.6662	.6722	.6782	.6842	.6902	.6962	.7022	.7052	.7143	.7203	.7263	.7323	.7383	.7443
2.68	.6578	.6637	.6697	.6757	.6817	.6877	.6936	.6996	.7056	.7116	.7176	.7235	.7295	.7355	.7415
2.69	.6553	.6613	.6672	.6732	.6792	.6851	.6911	.6970	.7030	.7089	.7149	.7209	.7268	.7328	.7387
2.70	.6529	.6588	.6648	.6707	.6766	.6826	.6885	.6944	.7004	.7063	.7123	.7182	.7241	.7301	.7360
2.71	.6505	.6564	.6623	.6682	.6741	.6801	.6860	.6919	.6978	.7037	.7096	.7155	.7214	.7274	.7333
2.72	.6481	.6540	.6599	.6658	.6717	.6776	.6834	.6893	.6952	.7011	.7070	.7129	.7188	.7247	.7306
2.73	.6457	.6516	.6575	.6633	.6692	.6751	.6809	.6868	.6927	.6986	.7044	.7103	.7162	.7220	.7279
2.74	.6434	.6492	.6551	.6609	.6668	.6726	.6785	.6843	.6902	.6960	.7019	.7077	.7136	.7194	.7252
2.75	.6410	.6469	.6527	.6585	.6643	.6702	.6760	.6818	.6876	.6935	.6993	.7051	.7110	.7168	.7226
2.76	.6387	.6445	.6503	.6561	.6619	.6677	.6735	.6793	.6852	.6910	.6968	.7026	.7084	.7142	.7200
2.77	.6364	.6422	.6480	.6538	.6595	.6653	.6711	.6769	.6827	.6885	.6943	.7000	.7058	.7116	.7174
2.78	.6341	.6399	.6456	.6514	.6572	.6629	.6687	.6745	.6802	.6860	.6918	.6975	.7033	.7090	.7148
2.79	.6318	.6376	.6433	.6491	.6548	.6606	.6663	.6720	.6778	.6835	.6893	.6950	.7008	.7065	.7123
2.80	.6296	.6353	.6410	.6467	.6525	.6582	.6639	.6696	.6754	.6811	.6868	.6925	.6983	.7040	.7097
2.81	.6273	.6330	.6387	.6444	.6502	.6559	.6616	.6673	.6730	.6787	.6844	.6904	.6958	.7015	.7072
2.82	.6251	.6308	.6365	.6422	.6478	.6535	.6592	.6649	.6706	.6763	.6819	.6876	.6933	.6990	.7047
2.83	.6229	.6286	.6342	.6399	.6456	.6512	.6569	.6625	.6682	.6739	.6795	.6852	.6909	.6965	.7022
2.84	.6207	.6264	.6320	.6376	.6433	.6489	.6546	.6602	.6659	.6715	.6771	.6828	.6884	.6941	.6997
2.85	.6185	.6242	.6298	.6354	.6410	.6466	6523	.6579	.6635	.6691	.6748	.6804	.6860	.6916	.6973

TABLE 1 (Cont'd)
FIELD SECTION 501
Absolute Volumes Per Pound of Material

Specific Gravity	Absolute Volume in Cu. Ft.	Specific Gravity	Absolute Volume in Cu. Ft.
2.36	0.006790526	2.61	0.006140092
2.37	0.006761874	2.62	0.006116657
2.38	0.006733463	2.63	0.006093400
2.39	0.006705289	2.64	0.006070319
2.40	0.006677350	2.65	0.006047412
2.41	0.006649644	2.66	0.006024677
2.42	0.006622166	2.67	0.006002113
2.43	0.006594914	2.68	0.005979717
2.44	0.006567886	2.69	0.005957487
2.45	0.006541078	2.70	0.005935423
2.46	0.006514488	2.71	0.005913521
2.47	0.006488114	2.72	0.005891780
2.48	0.006461952	2.73	0.005870198
2.49	0.006436000	2.74	0.005848774
2.50	0.006410256	2.75	0.005827506
2.51	0.006384718	2.76	0.005806392
2.52	0.006359381	2.77	0.005785430
2.53	0.006334245	2.78	0.005764619
2.54	0.006309308	2.79	0.005743957
2.55	0.006284565	2.80	0.005723443
2.56	0.006260016	2.81	0.005703075
2.57	0.006235658	2.82	0.005682851
2.58	0.006211489	2.83	0.005662771
2.59	0.006187506	2.84	0.005642831
2.60	0.006163708	2.85	0.005623032
		3.15	0.005087505

Inter-Office Correspondence

MISSOURI DEPARTMENT OF TRANSPORTATION

DATE: February 13, 1991

TO:

FROM: ____________________
District Operations Engineer

SUBJECT: Materials
Portland Cement Concrete Mix Proportions

	Wt./Cu. Ft.	Sp. Gr.	% Absorption
Sand			
Stone			
Fly Ash			

Class of Concrete	Mix Proportions	Water/ Cement Ratio	% Air	% Air in Mortar	Cement Factor	Dry Yield for 27.0 Cu.Ft	DRY WEIGHT - (27.0 CU.FT.) CEMENT		Fly Ash	Fine Agg	Coarse Agg
		Gal./Sk					Lbs.	Sacks	Lbs.	Lbs.	Lgs.

Exhibit 501-A Portland Cement Concrete Mix Proportions

MATERIALS
ENGINEERING